PHYSICS 312 — Syllabus

Course Credit: 3 semester hours.
Lectures: MWF, 11:00-11:50am.
Format: A lecture course with weekly problem sets, a midterm exam and a final exam.

List of Topics

Brief review of key concepts and the Hydrogen-atom problem

Addition of Angular Momenta — Clebsch-Gordan Coefficients

Approximation Methods for Bound-State Problems
- Variational method.
- Perturbation theory (time independent).
- Degenerate case.
- Zeeman effect without spin. Stark effect.

Fine Structure of Hydrogen
- Relativistic kinematic correction.
- Spin-orbit coupling.
- Zeeman effect with spin.

Identical Particles
- Bosons and fermions. Pauli Exclusion Principle.
- Interaction between identical particles — exchange term.

Multielectron Atoms
- Central-field approximation. Shell structure.
- Corrections to central-field approximation. Hund's rules

Molecules
- Ionic and covalent bonds.
- Born-Oppenheimer approximation.
- Vibration and rotation spectra.

Time-Dependent Perturbation Theory
- General formalism. Harmonic case. Long-time limit.
- Fermi's Golden Rule.
- Interactions of atoms with classical electromagnetic fields.
- Adiabatic approximation. Sudden approximation.

Scattering Theory
- Born Approximation.
- Partial waves. Phase shifts. Optical theorem.
- Low-energy scattering: scattering length.

Mixed States and the Density Matrix

Brief introduction to Relativistic Quantum Physics
- Relativistic wave equations. Klein paradox.
- Free field theory. Quantized EM field; photons.

Objectives: To learn how to use approximate methods (perturbation theory, variational principle) to solve a variety of problems of quantum mechanics. To learn how relativistic effects enter the description of the Bohr atom, and how they demonstrate themselves in multi-electron atoms. Master the basics of the chemical bonding in molecules, and the structure of molecular spectra. Learn scattering theory, as an important constituent of modern AMO physics.

Learning outcomes: To be able to understand and utilize the approximate methods of quantum mechanics in order to solve typical problems similar to those encountered in the homeworks. To master conceptually the effects of the Fermi statistics and interactions in multi-electron atoms and molecules. To learn how light interacts with matter at the level of non-relativistic quantum mechanics. Grasp basic ideas behind relativistic formulation of quantum mechanics and the fundamental need for a different framework (namely, quantum field theory) to fully describe relativistic quantum effects.

Text (recommended): Townsend, *A Modern Approach to Quantum Mechanics* (University Science Books, 2nd Ed. 2012). Note: the 1st edition is perfectly fine as well

The lecture notes by P. Stevenson and A. Nevidomskyy (available through Rice Bookstore) are self-contained and can be used without a textbook for self-study.